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The prediction of co-channel interference to television broadcasting services in the frequency range 470 to 960 MHz

No. 1969/33

Research Department, Engineering Division
THE BRITISH BROADCASTING CORPORATION

RESEARCH DEPARTMENT

THE PREDICTION OF CO-CHANNEL INTERFERENCE TO TELEVISION BROADCASTING SERVICES IN THE FREQUENCY RANGE 470 TO 960 MHz

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SUMMARY

The operation over a period of four years of a computer programme designed to assist with the planning of a network of television transmitters has revealed the need to carry out certain modifications. A description is given in this report of the revised method of calculating field strengths which has been incorporated in the programme. The calculation may also be carried out manually and this process is described.

1. INTRODUCTION

Since 1964, the BBC Research Department has used a digital computer to help with the planning of a u.h.f. transmitter network. The programme is designed to evaluate the levels of interference caused by transmitting stations sharing the same channel. The development of this project was the subject of an earlier report[1] and is not discussed in detail here. However, for a full understanding of the contents of this report it is desirable that the earlier paper should have been read.

An important feature of the project was a new method of calculating field strengths which gave a considerable improvement in accuracy over that previously used since the European Broadcasting Conference at Stockholm in 1961. Unfortunately this new method still possessed some disadvantages, and further modifications have been devised.

In this report three distinct methods of field strength calculation are considered:—

(1) The process used at Stockholm in 1961[2]
(2) The method devised by the BBC Research Department in 1964[1]
(3) The modifications now adopted

These are referred to as 'Stockholm', 'first' and 'second' methods respectively.

Section 2 of this report discusses the disadvantages of the first method; Section 3 outlines the second method, and Section 4 gives greater detail whilst describing how the calculation may be completed manually.

2. DISADVANTAGES OF THE FIRST METHOD

At the time of its introduction it was realized that there were certain disadvantages in the first method. For example, the calculation was cumbersome, but this was accepted because it did not involve much additional computer time. In any case the demand for the rapid development of the u.h.f. service disallowed further delay for improvement. During the subsequent four years of operation various other shortcomings have become apparent. In some cases ad hoc modifications were devised to overcome difficulties and indeed the whole period has been one of continuous development.

In the second half of 1967, new field strength measurements confirmed the suspicion that substantial revision of the calculation technique was necessary. Thus at that time it was decided to revise the first method and simultaneously to incorporate other changes which were outstanding. The timing of this revision coincided with the necessity to rewrite the computer programme in Fortran IV (previously the language used was Elliott Autocode).

The first method was based upon the expression:

$$E = E_o + P - L_u - F_1 - F_2 + T_c \qquad (1)$$

where E = field strength (in dB μV/m) of the interfering signal*
E_o = free-space field strength (in dB μV/m) for 1 kW e.r.p.
P = e.r.p. in dB rel 1 kW
L_u = urban factor (dB)
F_1 = a factor proportional to path length (dB)
F_2 = an additional factor proportional to path length beyond nominal horizon (dB)
T_c = terrain correction (dB), a gain or loss depending on the ground profile close to the terminals

The re-investigation leading to the preparation of the second method covered the factors listed below (together with others of lesser importance) and the subsequent adjustment of the mathematical model.

---

* Field strengths in this report are quoted in dB μV/m, i.e. dB relative to 1 μV/m.

(i) The results which became available in 1967 showed that predictions made for receiving sites in the region immediately beyond the horizon were high when compared with measurement. This confirmed that the loss experienced beyond the horizon was not linear with distance (conflicting with Equation (1) above). It was clear that the attenuation rate is greatest just beyond the horizon but thereafter diminishes as the distance increases.

(ii) A computer-assisted investigation into tropospheric ray tracing suggested deficiencies in the earth-curvature correction which was employed in the first method.

(iii) The sea-path data used to develop the first method were obtained from measurements of transmissions from low transmitting aerial heights. The ray-tracing investigation together with a study of the statistics on the occurrence of refractive index gradients[3] suggested that the high field strengths measured for small percentages of the time would not necessarily be increased by raising the aerial height. This is attributed to the fact that the high refractive index gradients, which bend the ray in such a fashion as to produce high field strengths at receiving terminals near the ground, occur more frequently at low heights.

(iv) The first method employed linear interpolation in arriving at predictions for mixed land/sea paths. At the time of its introduction other more elaborate methods had been considered, but they yielded little additional benefit. Linear interpolation was, therefore adopted because of its simplicity, but it later became clear that some improvement was both necessary and attainable.

(v) The evidence for the evaluation of the urban factor L_u gave little overlap in the domains of urban and non-urban measurements. In general, the urban measurements were for 50% time and were available for ranges of less than 100 km whilst the non-urban measurements were for greater ranges and represented smaller time percentages.

(vi) The process of re-definition of the terrain correction angle used in the first method was extremely complex. In particular, the procedure employed for receiving sites beyond the horizon could produce a condition of negative height gain, which was suspect. Also the determination of height gain in the first method was complicated.

(vii) The terrain correction curve employed in the first method was based upon a set of linearly interpolated points. If an exponential form is assumed it is possible to optimize this using a computer and thus greater accuracy may be obtained.

(viii) The required result is for a field strength value protected for 95% of the time. In the first method this was based upon a field strength/time distribution derived from 1% and 10% values. A more accurate result could be obtained using 1% and 5% values. The 50% time value is also of importance when dealing with signals which have small variations with time. Therefore calculations for this time level were also investigated because derivation from 1% and 5% time values assuming log-normality is not sufficiently accurate.

Before describing the second method, it is pertinent to mention the tropospheric ray-tracing examination which was carried out.[4] Originally it was hoped to produce parameters based upon meteorological factors which would allow field strength to be assessed more accurately in terms of time. Although much measured data were available for the development of the first method, the situation was confused because of the considerable differences between results nominally quoted for the same distances and time percentages. By identifying the meteorological effects, it was hoped to reduce inherent errors, but it was not possible to obtain adequate weather data for the propagation paths which had been measured. Thus the improvements realized in the first method over that used at Stockholm were achieved mainly by taking into account the effect of local terrain. However, the ray-tracing investigation was most useful, and at least provided philosophical guidance in the preparation of the second method.

3. THE SECOND METHOD

3.1. General

The second method is now outlined in two stages. Firstly a description is given of the four sets of propagation curves which form the basis of the method. Secondly, the various corrections are described. These corrections allow the values prescribed by the propagation curves to be adjusted for the unique conditions of each path.

The coefficients used to specify the propagation curves and correction factors were derived by a computer optimization programme which obtained minimum difference between predicted and measured values.

3.2. The Propagation Curves

The basic propagation curves used in the calculation are plotted as straight lines on logarithmic/linear graph paper, depicting field strength in decibels as a function of logarithmic distance. Figs. 1 to 4 illustrate these curves, and for description purposes each curve may be separated into four sections.

(i) The curve depicting free-space field strength.

(ii) The curve showing decay within horizon range. Applicable to overland paths only, this curve diverges from (i), its steeper slope being attributed to 'clutter' and terrain effects not defined in the calculation.

(iii) The curve covering the 'trans-horizon' range. This is the region within which increased attenuation occurs, due to the diffraction loss which takes place as the earth's curvature obstructs the propagation path.

(iv) A curve defining the decay which takes place in the scatter region at still greater distances beyond the horizon.

The onset of the trans-horizon loss is dependent on d_h, which is given by:—

$$d_h = 4{\cdot}12\,(\sqrt{h_1} + \sqrt{h_2}) \qquad (2)$$

where d_h = combined horizon distance (km), i.e. the sum of horizon distances from the transmitting and receiving aerials

h_1, h_2 = terminal aerial heights (metres above sea level).

The calculation of horizon range assumes normal refractive conditions, i.e., four-thirds true Earth's radius.

There are certain exceptions to the rigorous application of the above formula in deciding the onset of the trans-horizon loss. Taking first the oversea case, the effective horizon distance (d_h') used in conjunction with the oversea curves for 1% and 5% times is taken to be equal to d_h except that it is not allowed to fall below a minimum value (d_h min). This is an empirical adjustment based upon the premise that refractive index conditions can produce free-space fields at very long ranges, even with low terminal heights. On measured evidence it was decided to place this lower limit on d_h to prevent the application of too much attenuation. It was also decided that trans-horizon loss would not be applied to path lengths of less than 32 km.

Reference to Figs. 2, 3 and 4, which illustrate the overland conditions, reveals that the onset of the trans-horizon loss is established at an effective horizon distance $d_h' = d_h - 20$ km. This is an allowance to take into account the horizon-shortening effect of terrain undulations: it is quite arbitrary because, as will be seen later, no information is available in the computer storage about ground heights in the intervening path beyond 16 km from each terminal.

A considerable amount of attention was devoted to the mixed-path calculation. The technique finally adopted in the second method requires the derivation of calculated results for all-land and all-sea paths, subsequent interpolation between these being a linear function of the percentage of sea in the paths except for propagation paths greater in length than d_h for 1% and 5% times. In these cases the interpolation takes the form

$$E_M = E_L + A(E_S - E_L) \qquad (3)$$

where E_M, E_L, and E_S are field strengths in decibels for mixed, land and sea paths respectively, and the interpolation factor A is given by

$$A = 1 - (1 - F)^x \qquad (4)$$

where F = fraction of sea, i.e. $\dfrac{\text{length of path over sea}}{\text{total path length}}$

x = exponent derived from optimization programme.

3.3. Corrections

Having used path-length and aerial-height information to extract values from the propagation curves, these field strengths are corrected by factors which further define each situation. Apart from the simple correction for e.r.p. (since the propagation curves are produced for an e.r.p. of 1 kW), two basic adjustments are necessary. These are the urban factor, and the local terrain correction.

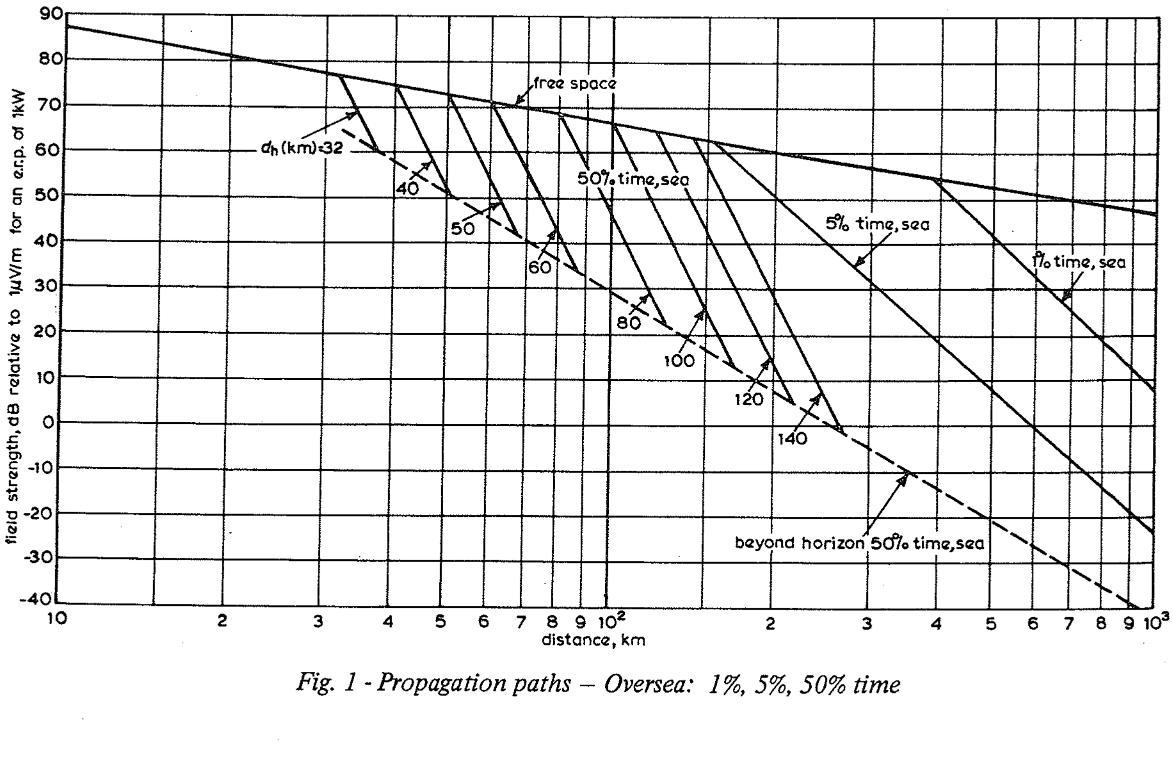


Fig. 1 - Propagation paths – Oversea: 1%, 5%, 50% time

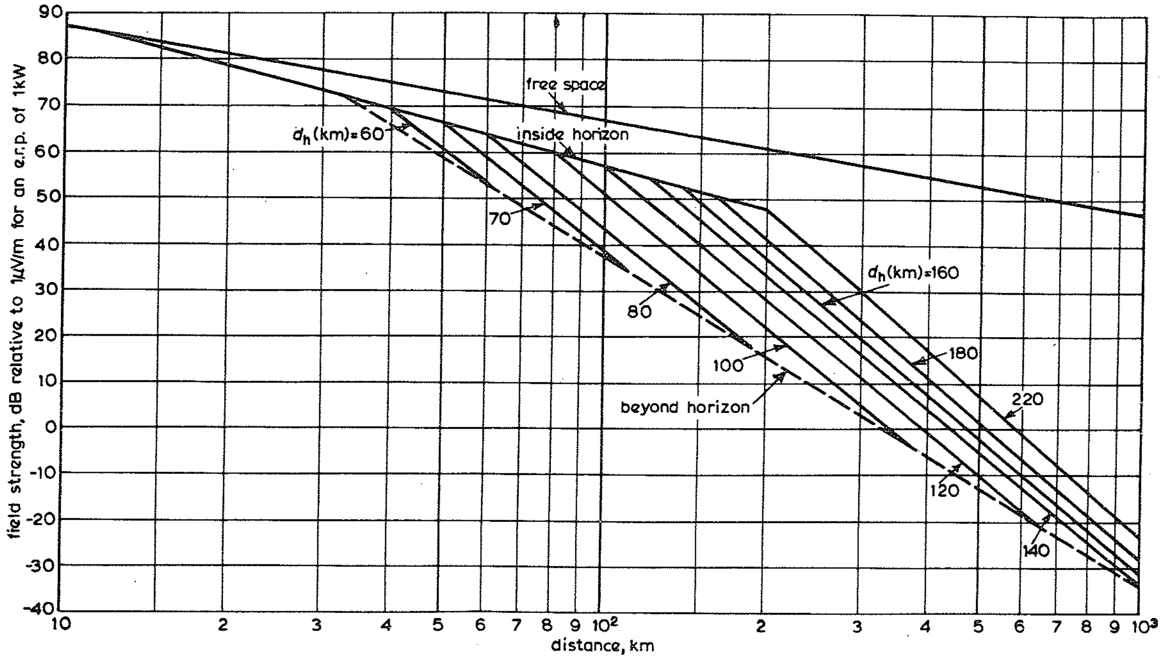


Fig. 2 - Propagation paths – Overland: 1% time

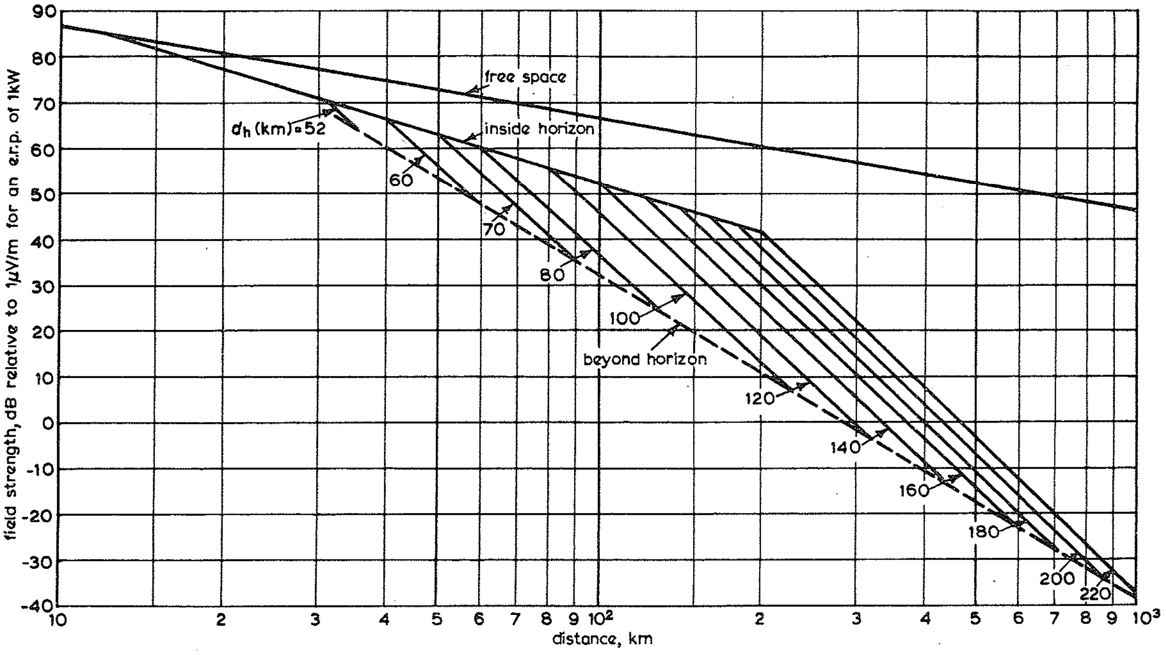


Fig. 3 - Propagation paths – Overland: 5% time

The so-called 'urban factor' (applicable to domestic reception in built-up areas) is a constant loss of 10 dB. It represents the attenuation caused by surrounding buildings, and is always applied in the calculation unless an answer is required for an 'open' site, such as one to be used for high-grade reception for rebroadcasting purposes.

The local terrain correction is applied to both transmitting and receiving ends of the propagation path. It defines attenuation only, and depends upon the ground profile within 16 km of each terminal. It is expressed by

$$T_c = C_1\,[1 - \exp\{C_2\,(\alpha - C_3)\}] \qquad (5)$$

where T_c = local terrain correction (dB)

C_1 (dB), C_2 (deg^{-1}), and C_3 (deg) are factors determined by optimization.

α = angle (degrees) between the datum (defined below) and the line to the dominant obstacle within 16 km.

The application of formula (5) in the calculation is complex, and the features are discussed in detail later in Section 4. At this stage it is adequate to outline the important details.

Where the length of the propagation path exceeds 32 km, the total terrain correction consists of the sum of the

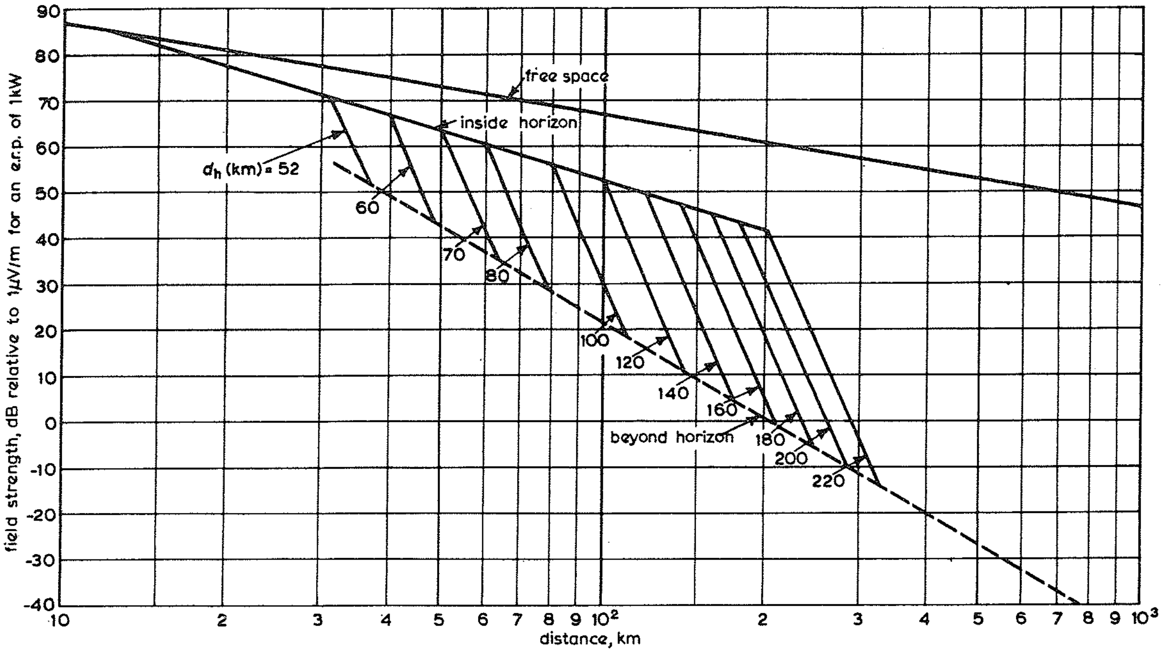


Fig. 4 - Propagation paths – Overland: 50% time

individual attenuations calculated for both ends of the path. For shorter distances, a single correction is used, and the derivation of this is dependent on the path length, terminal heights and terrain angles.

The angle α is obtained from a process of redefinition. Briefly, the angle which is contained in the computer store is measured from the horizontal at each site, and is referred to as θ. The sign of this angle is negative when the terrain within 16 km of the site is above the horizontal. However, the datum used in the calculation to define the angle α depends upon other factors, so a process of redefinition is employed to convert the measured angle θ into the correction angle α. For example, if the distance between terminals is less than d_h, the datum used is the line joining the aerials, thus redefinition is necessary. However, if the path extends beyond the horizon the datum line is the horizontal at each point, and in this case $\alpha = \theta$.

3.4. Optimization Factors

The formulae upon which the calculation is based contain a number of coefficients. To derive these, an optimization programme was performed, following the preparation of the mathematical model, the value of each coefficient being varied until minimum error was observed between prediction and measurement.

Twenty-four of the optimized coefficients are included in the formulae defining the propagation curves. As indicated earlier, the curves show field strength in decibels as a linear function of logarithmic distance. Thus,

Field strength (dB µV/m) = $B - m \log_{10}$ [distance (km)] (6)

where B = field strength in dB (µV/m) at 1 km
m = gradient of curve

To identify each of the coefficients used in the definition of the propagation curves, it is appropriate to consider the latter in the four transmission categories named in Section 3.2, namely,

(i) free-space
(ii) within horizon range
(iii) trans-horizon zone
(iv) scatter zone

For the free-space condition

$$m = 20 \quad : \quad B = 107 \text{ dB } (\mu\text{V/m})$$

For transmission within the horizon

$$m = m_i \text{ (values shown in Table 1)}$$
$$B = B_i \text{ (values shown in Table 1)}$$

For transmission in the trans-horizon region,

$$m = m_t = K_1 + K_2.d_h' \text{ (values shown in Table 1)}$$

$$B = B_t = [B_i + (m_t - m_i) \log_{10} d_h']$$

For the scatter zone,

$$m = m_s \quad : \quad B = B_s \text{ (values shown in Table 1)}$$

For mixed path propagation, Table 1 gives the values of the exponent x (see formula 4).

Table 1 identifies the coefficients listed above, and shows the number of measurements which have been used in each case to provide evidence. The measurements used for the short ranges (<100 km) are mainly median values, i.e., they are the results of many thousands of individual observations made in built-up areas. They are 50% time values, whereas measurements made at longer ranges are invariably the results of protracted observations at selected receiving sites to observe the variations of F/S as a function of time, and these are quoted for various time percentages.

Table 1 also indicates the degree of error inherent in the system. It is noted that the standard deviation of all errors is 6·8 dB, and this may be compared with figures of 8·3 dB for the first method, and 12·6 dB for the Stockholm technique. A comparison has also been made between the errors of the 1% time values produced by the first and second methods.

4. COMPUTATION PROCEDURE

The first and second methods have both been devised for calculation by a digital computer. However, the second method can be employed manually, although such a process could only be regarded as meeting an occasional requirement. The number of calculations involved in routine u.h.f. planning work demands the employment of a computer, but the facility allowing manual computation is an advantage. A description of the process is now given, and this will also serve to illustrate the sequence followed by the computer programme.

The data required for the calculation are as follows:

(a) Heights of terminal aerials above sea level.

(b) Length of transmission path.

(c) The land/sea ratio.

(d) Terrain clearance angles (θ) for both transmitting and receiving ends.

(e) E.R.P. information

There are six stages of the calculation.

The first stage is to determine the combined horizon distance (d_h) of the terminal aerials. This process uses formula (2), and d_h may be obtained by employing Nomogram 1, which has been produced from this formula.

With overall and horizon distances available, the second stage may be carried out. This involves the use of the appropriate field strength/distance curves (Figs. 1 to 4). If the path is all-sea, Fig. 1 alone is necessary; if it is completely over land, Figs. 2, 3 and 4 are used; if it is a mixed path, values must be obtained from all four curves. On each graph, the line used is that which corresponds to d_h, and the field-strength value is read for the total distance.

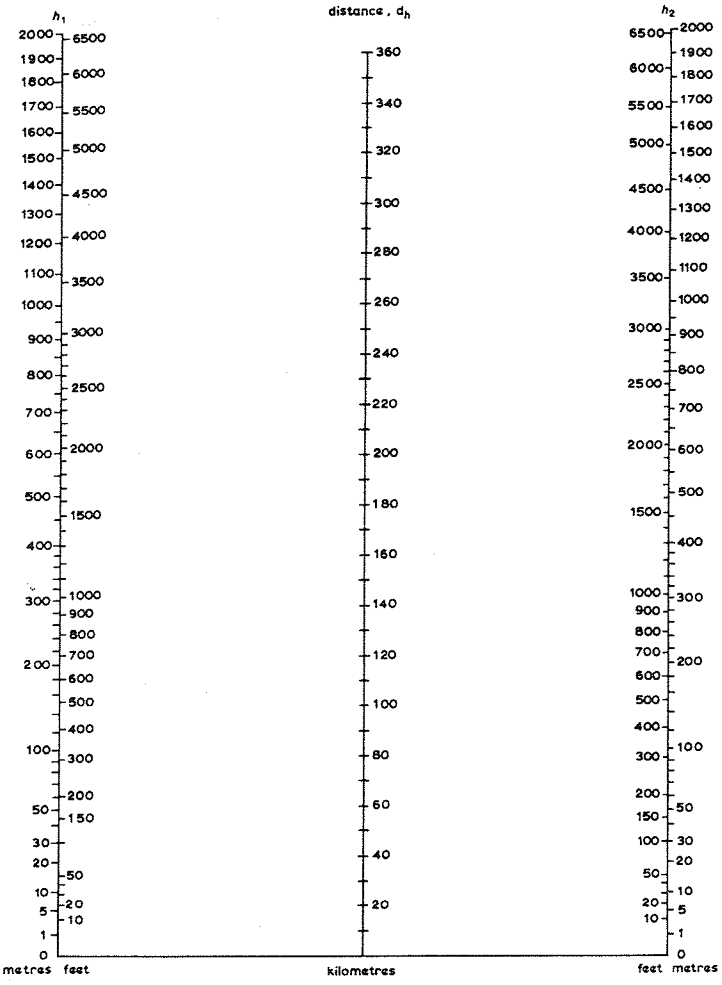
TABLE 1

Path	% Time	COEFFICIENTS							Number of Measurements	Standard Deviation of Error (dB)	
		m_i	K_1	K_2	B_i (dB)	B_s (dB)	d_h min (km)	x		Second Method	First Method
Land	50	35·7	260·8	0	124	164	32	–	320	6·7	
	5	35·7	100·7	0·07	124	174	32	–	28	7·3	
	1	30·4	87·4	0·07	188	179	32	–	34	7·4	9·7
Sea	50	20	235	0	107	164	32	–	5	4·6	
	5	20	91·3	0·07	107	174	153	–	10	2·6	
	1	20	87·4	0·07	107	179	383	–	13	5·5	8·5
Mixed	50	–	–	–	–	–	–	1	56	6·6	
	5	–	–	–	–	–	–	0·784	15	5·2	
	1	–	–	–	–	–	–	0·656	20	9·7	13·5

Other coefficients relating to all paths:

Urban loss L_u = 10 dB
Terrain Correction C_1 = –26·075 dB
Terrain Correction C_2 = 1·3717 deg^{-1}
Terrain Correction C_3 = 0·221 deg.

Slope of 'scatter' curve m_s = 71
Total number of measurements analysed = 501
Standard deviation of overall error = 6·8 dB



Nomogram 1 - Calculation of horizon distance

The second stage thus provides field strength values representing 1%, 5% and 50% of the time. If a mixed path is involved, six such values will be available at the end of the second stage, and it is necessary to interpolate between these land and sea results. This is done by using Fig. 5 which has been produced from formula (4). This mixed-path assessment constitutes the third stage of the calculation.

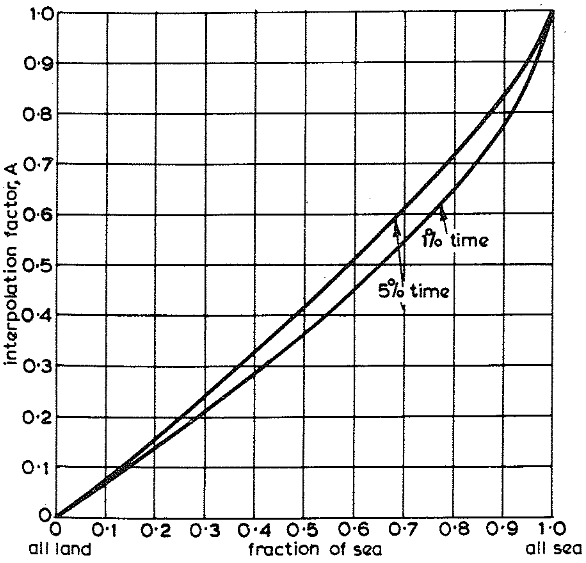


Fig. 5 - Land/sea interpolation factor

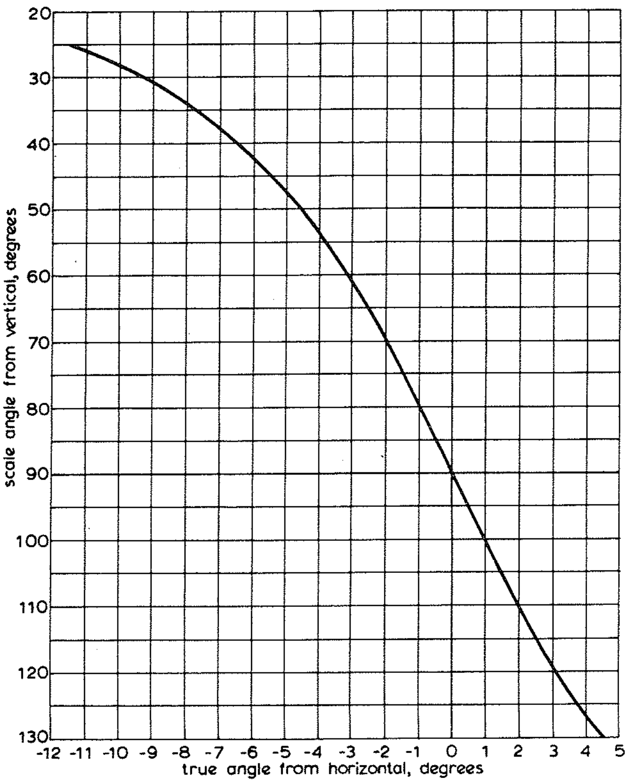


Fig. 6 - Terrain angle – scale to true conversion curve for use in conjunction with a vertical/horizontal scale ratio of 10·56/1

The fourth stage involves the application of corrections determined by the terrain clearance angles (θ). At present, the angles obtained for each terminal are measured from the vertical using an instrument known as a terrain clearance protractor.[5] This produces a scale angle, and it is first necessary to convert this scale angle into the true angle θ which is measured from the horizontal. This process is carried out by using Fig. 6.

The derivation of the correction based upon the terrain clearance angle depends upon the length of the path involved. It will be appreciated that since the terrain angles are only assessed from the terrain within 16 km of each terminal, the complete height data over path lengths greater than 32 km are not available. This distance therefore constitutes a boundary: for paths of greater length, corrections are obtained for both transmitting and receiving ends, and are then added together. For shorter paths, a single correction is obtained. Also, the datum used to define the terrain correction angle in the calculation is related to the length of path. For this reason it is necessary to discriminate between θ, the true angle measured from the horizontal, and α, the angle actually used in the calculation. In the following description the path lengths are separated into four categories in order to illustrate the differences.

(i) Path lengths exceeding d_h. For these longer paths the angle θ derived for each terminal is taken without further adjustment, i.e. $\alpha = \theta$.

(ii) Path lengths less then d_h but greater than 32 km. Here the datum used for the assessment of the terrain clearange angles is the straight line joining the terminal aerials. Thus it is necessary to define α as shown

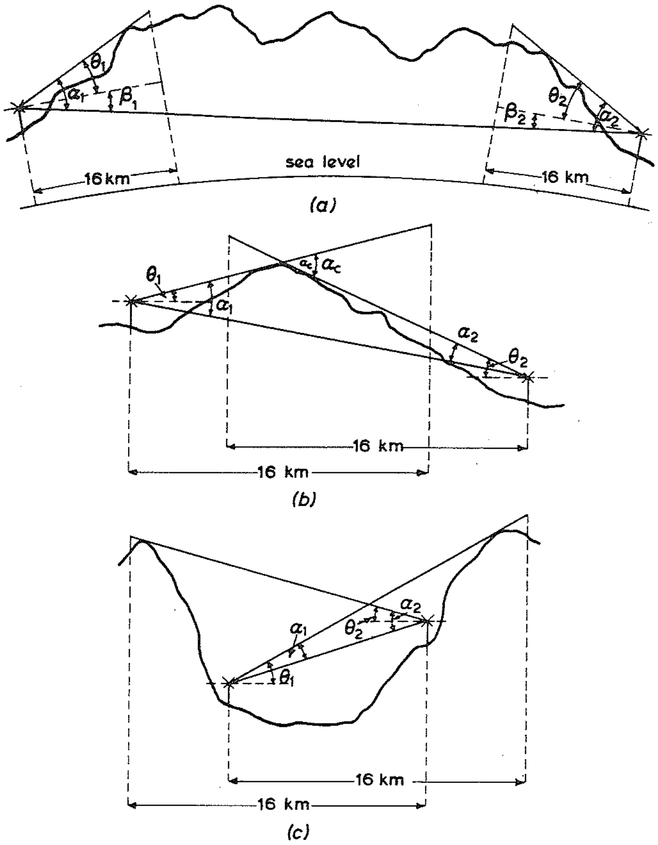


Fig. 7 - Terrain angle – examples of redefinition of angle

in Fig. 7(*a*) from which

$$\alpha = \theta - \beta \qquad (7)$$

where β is the angle between the horizontal and the new datum line, and is positive if this datum is below the horizontal. It is calculated from:–

$$\beta_1 = 0{\cdot}0573 \left[\frac{d}{(4{\cdot}12)^2} + \frac{h_1 - h_2}{d} \right] \text{ degrees} \qquad (8)$$

The factor 0·0573 is a conversion allowing for heights in metres and distances in kilometres; it also converts the angle from radians into degrees. Angle α may be determined using Nomogram 2. Note that in using this figure, h_1 refers to the terminal for which re-definition is being completed.

(iii) Path lengths between 16 and 32 km. In this case the terrain angles obtained for each terminal take into account all of the obstacles in the path. Referring to Fig. 7(*b*) a single correction is derived, based on the following values of a combined angle, α_c.

$\alpha_1 \geqslant 0{\cdot}221$	$\alpha_2 \geqslant 0{\cdot}221$	: no correction*
$0{\cdot}221 > \alpha_1 \geqslant 0$	$0{\cdot}221 > \alpha_2 \geqslant 0$	: $\alpha_c = 0$
$\alpha_1 < 0$	$\alpha_2 \geqslant 0$	: $\alpha_c = \alpha_1$
$\alpha_1 \geqslant 0$	$\alpha_2 < 0$	: $\alpha_c = \alpha_2$
$\alpha_1 < 0$	$\alpha_2 < 0$	: $\alpha_c = \alpha_1 + \alpha_2$

(iv) Path lengths less than 16 km. It will be appreciated that in this case the terrain angle information provided for each terminal completely overlaps, as shown in Fig. 7(*c*). As in category (iii), a single correction based upon an angle α_c is applied, and the values are as follows:–

$\alpha_1 > 0{\cdot}221$	α_2 any value	: no correction
α_1 any value	$\alpha_2 > 0{\cdot}221$	: no correction
$0{\cdot}221 \geqslant \alpha_1 \geqslant 0$	$0{\cdot}221 \geqslant \alpha_2 \geqslant 0$	: $\alpha_c = 0$
$\alpha_1 < 0$	$0{\cdot}221 \geqslant \alpha_2 > 0$	: $\alpha_c = \alpha_2$
$0{\cdot}221 \geqslant \alpha_1 > 0$	$\alpha_2 < 0$	: $\alpha_c = \alpha_1$
$\alpha_1 \leqslant 0$	$\alpha_2 \leqslant 0$	: $\alpha_c = \alpha_1 + \alpha_2$

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* It will be seen from Fig. 8 that angle $\alpha = 0{\cdot}221^\circ$ corresponds to zero correction. This value resulted from the optimization programme (coefficient C_3).

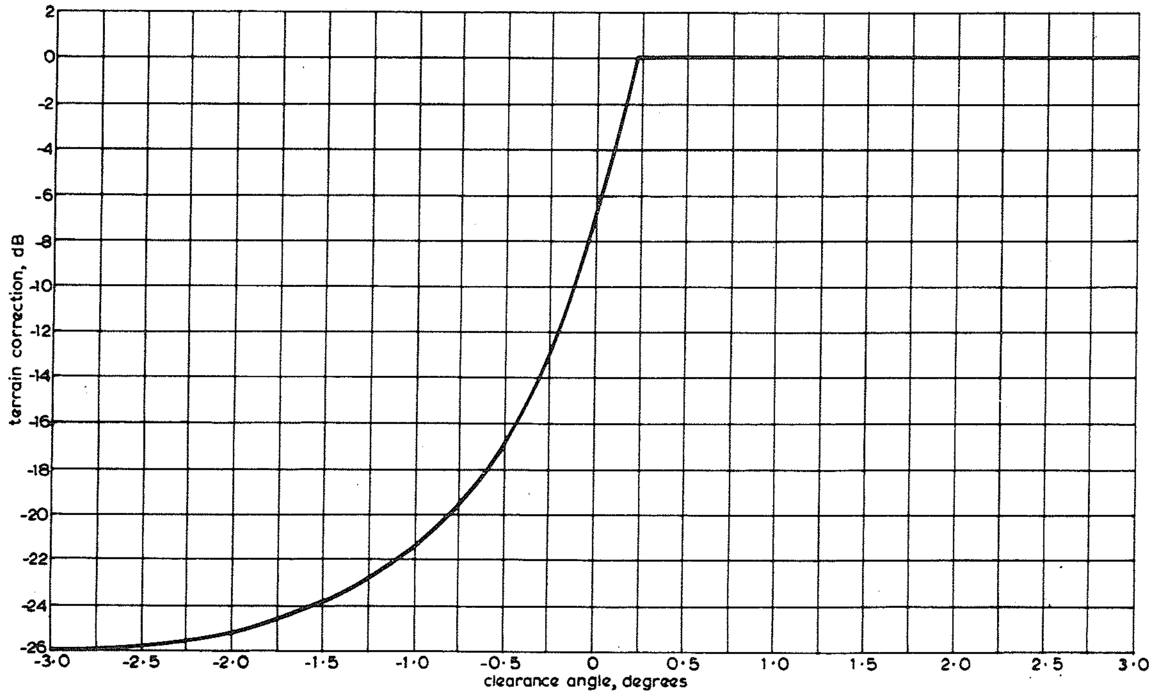
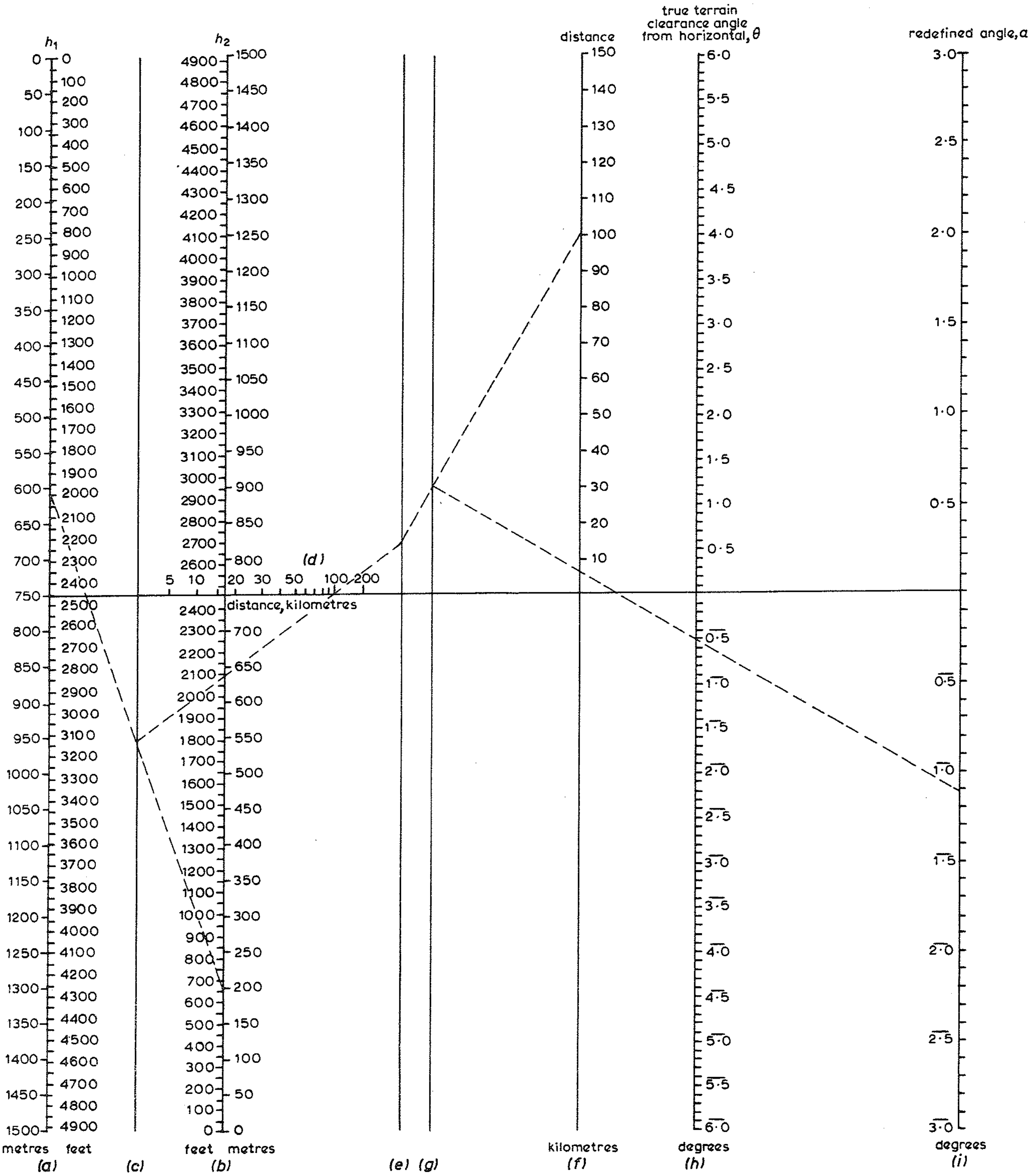


Fig. 8 - Terrain angle – correction curve



Nomogram 2 - Calculation of redefined angle α

– – – – – – example with (*a*), (*b*), (*c*) etc. in sequence

It will be realized that in this particular instance the terrain angles could be decided by features outside the propagation path, a clearly anomalous condition which is illustrated by Fig. 7(*c*). Currently this is not avoided in the computer programme, and there is little incentive at present to solve it because the process is designed to assess co-channel interference problems, and the situation identified in the figure is extremely unlikely to occur in practice.

With angle α determined, the appropriate correction is read from Fig. 8. This correction is applied to the three field-strength values resulting from the earlier stages, namely the 1%, 5% and 50% time results. This leads to the fifth stage in the calculation, in which consideration is given to the question of long-term interference. This is an incidental adjustment, which has nothing to do with the field-strength calculation, but may modify the time distribution and hence the values which have been produced. The process is connected with the validity of the protection ratios which are used at a later stage in the calculation. The protection ratios defined by the CCIR are stated to be appropriate for those conditions where interference occurs for small percentages of the time 'not precisely defined, but assumed to be between 1% and 10%'. To take account of this requirement, the results from the calculation are checked to ensure that the 50% time figure is at least 10 dB below the 5% value. If this is not so, the 1% and 5% figures are increased by 10 dB less the actual difference.

The outcome of the fifth stage of the calculation, together with any necessary e.r.p. adjustments, is a graph (loosely defined by three points) of the distribution in time of the field strength of the selected transmission. The e.r.p. correction not only consists of an adjustment for the h.r.p. of the transmitting aerial, but also takes the v.r.p. into account. This is an important factor in the u.h.f. service, where vertical patterns are often extremely sharp, and beam tilt angles significant. Thus in the calculation of co-channel interference, the correction used is for that power assessed to cause the interference. The correction is determined as follows:

(i) The 'effective' vertical angle is taken to be the least positive of β or θ (see Fig. 7(*a*)). Let this be γ in radians.

(ii) Information is obtained concerning the vertical aperture A of the aerial (in wavelengths) and the beam tilt ϕ in radians.

(iii) Calculate $\psi = |\pi . A(\gamma - \phi)|$

(iv) If $\psi \geqslant \pi/2$ the correction is $20 \log_{10} 1/\psi$ in dB
If $\psi < \pi/2$ the correction is $20 \log_{10} \left(\frac{\sin \psi}{\psi}\right)$ in dB

At this stage, the urban loss factor may be deducted from the results if appropriate.

The sixth stage of the calculation concerns the conversion of the field strength distribution into a 'protected field strength' equivalent, i.e. the distribution of the wanted-signal level which would be required at the selected receiving site to render interference from the calculated transmission imperceptible. This consists of the addition of an appropriate protection ratio and an allowance for the directivity of the receiving aerial.

The protection ratio depends upon the relationship between the wanted and interfering carriers. The values currently used within the BBC Research Department are shown in Table 2. Further consideration is to be given to the question of protection ratios.

The field strength of the unwanted signal at the receiving site may be reduced by the directivity of the receiving aerial, provided this can discriminate between the directions of the wanted and interfering sources. Horizontal-radiation-pattern limits assumed for domestic and rebroadcast reception aerials currently used form Figs. 9, 10 and 11 of this report. Fig. 9 shows the assumed directivity and polarization discrimination for a domestic aerial, Fig. 10 for a horizontally-polarized r.b.r. aerial, and Fig. 11 for the vertically-polarized equivalent.

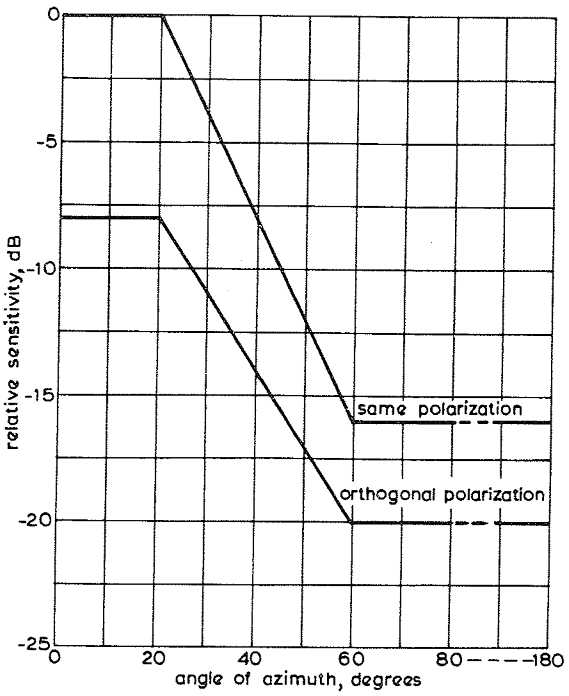


Fig. 9 - Horizontal radiation pattern limits for a domestic receiving aerial

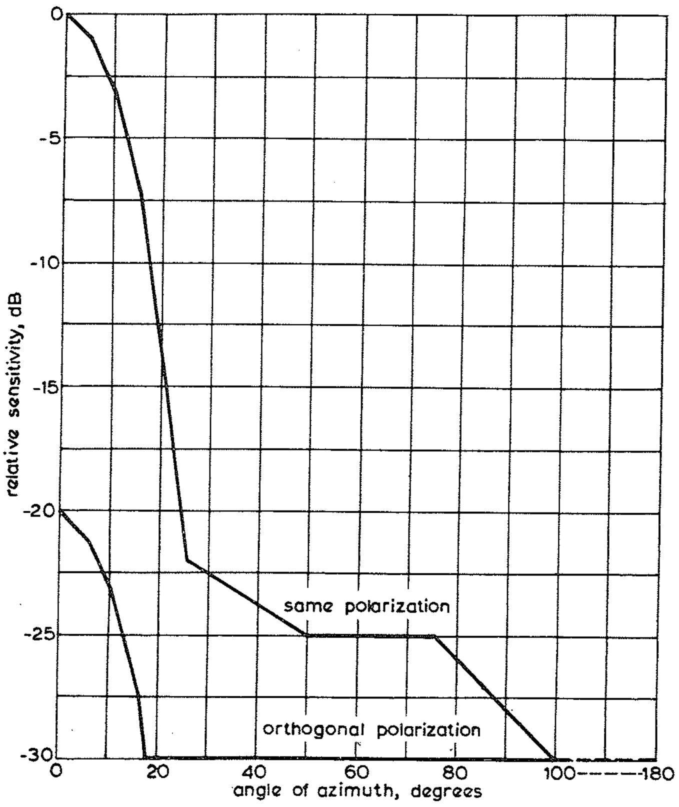


Fig. 10 - Horizontal radiation pattern limits for a r.b.r. aerial (horizontal polarization)

TABLE 2

Vision Carrier Separations	Protection Ratios (dB)
$\frac{3n \pm 1}{3}$ line (± 500 Hz)	30
$\frac{3n \pm 1}{3}$ line (± 2 Hz)	24
Nominally zero (± 500 Hz)	45
Nominally zero (± 2 Hz)	33
Exactly zero (active deflectors)	16

5. OTHER FEATURES OF THE PROGRAMME

The foregoing has described the calculation of the protected field strength of one station at a selected receiving site. Currently, the number of such calculations required for each receiving site selected for examination in the development work for the u.h.f. service can exceed 100. A full assessment of the co-channel interference situation on any one of the 44 transmission channels entails about 12,500 of these individual predictions, and over the period of the next five years or so the number of transmitters included in the programme is expected to double. The magnitude of the work introduces two other important features which, although they do not affect the prediction process described above, do influence the output and the running time of the computer programme. The first of these is the multiple interference assessment, i.e., the combination of the individual interfering contributions predicted for a selected receiving site into one distribution; the second is the exclusion procedure, whereby sources not contributing significantly to the overall interference level at any site are excluded from the calculation before detailed examination. These two features are briefly discussed below.

The multiple interference method used by the BBC Research Department since the inception of its computer programme to deal with the development of the u.h.f. service employs the probability-multiplication technique. This is fully described elsewhere[6] and is not discussed in detail here. It involves the consideration of both time and location variations of the signal over a small area which is represented by the selected receiving site, and the transformation of these individual variables into one known as the 'time-location' distribution, in which form the individual contributions from each interfering source are merged. This is carried out by multiplying together the individual probabilities, thereby producing one distribution representing the 'time-location' variate for the selected receiving site. This is then broken down into its two component parts so that a result may be quoted for protection in terms of time and location. The process assumes zero correlation between the interfering signals, this assumption being based upon observations.

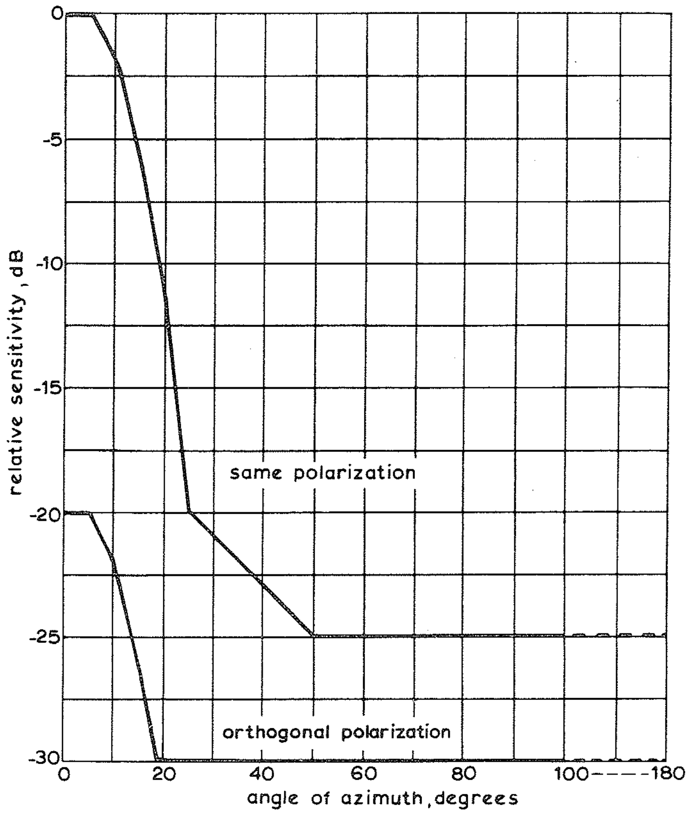


Fig. 11 - Horizontal radiation pattern limits for a r.b.r. aerial (vertical polarization)

Other methods of multiple interference assessment have been examined, namely simple power addition and convolution. Because these have shown little difference in the majority of results, the probability multiplication method has been retained. However, much work has been and is being carried out on the subject, and it seems likely that an alternative solution may be adopted in the near future.

The exclusion procedure, which is written into the existing programme, is designed to eliminate much unnecessary calculation. It is essential, of course, because the computer cannot intuitively discriminate between significant and insignificant sources. Two stages of exclusion are adopted. Firstly, European transmitters are not included in the store if it is decided that their transmissions will not interfere with service areas in the United Kingdom. This assessment is based upon a cautious estimate of the minimum distance requirements. Secondly, the computer is programmed to carry out a preliminary calculation for interference at the transmitting site of the area under examination. If the resultant protected field strength calculated from each potential interfering source is less than 40 dB (μV/m) for 98·8% of the time, then the transmitter in question is dropped from further calculation. This standard was established after analysing past results from which it transpired that contributions below this level were insignificant. This initial calculation does not take account of receiving aerial directivity (apart from the normal orthogonal polarization allowance, if any).

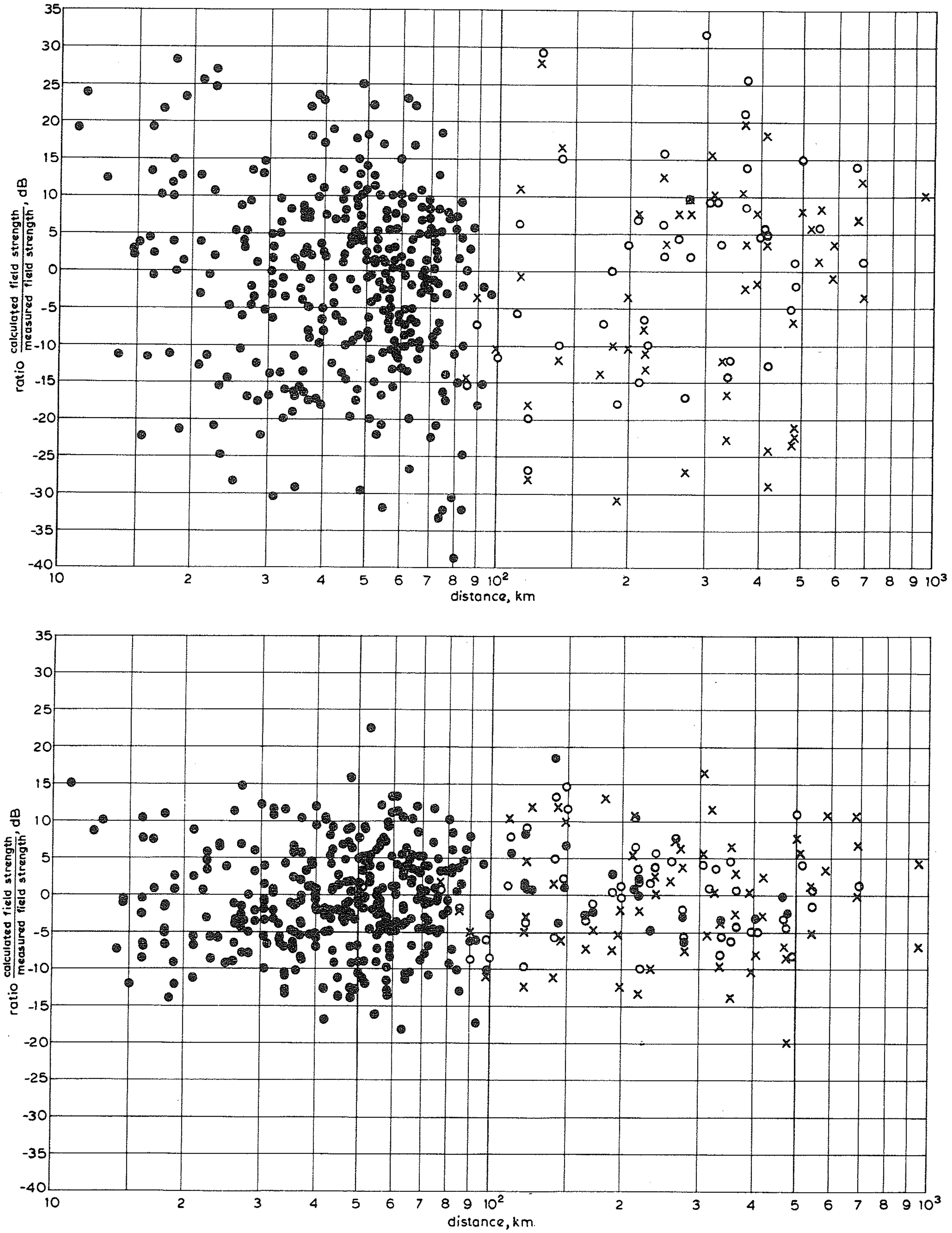


Fig. 12 - Comparison of calculated and measured field strengths

Upper graph - Stockholm Method

● 50% time ○ 10% time x 1% time

Lower graph - Second Method

● 50% time ○ 5% time x 1% time

6. CONCLUSIONS

The introduction of the second method of field strength calculation has resulted in a further useful improvement in accuracy which can be used to advantage in the planning of the u.h.f. service of the United Kingdom. Some idea of the extent of the improvement is given by Fig. 12, which compares the Stockholm method with the latest BBC technique.

Further improvement is certainly possible, and it is likely that this could be achieved by a more detailed analysis of individual results, in preference to the statistical techniques which have been employed so far. This applies especially to the short propagation paths, i.e., less than about 75 km in length. With the increasing density of u.h.f. transmitters, the ability to predict accurately the effects of co-channel interference at these short ranges becomes more important, and possible improvements are being studied. Modifications are also likely to be made to the multiple interference method, and work is now in hand to attempt to resolve outstanding problems in this sphere.

7. REFERENCES

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